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REPORT NO. RR-TN-66-3

EQUATIONS FOR COMPUTER PROCESSING U. S. WEATHER BUREAU RADIOSONDE TEMPERATURE AND RELATIVE HUMIDITY DATA

by

Novella S. Billions

August 1965

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809
Attn: AMSMI-RR

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EQUATIONS FOR COMPUTER PROCESSING U. S. WEATHER BUREAU RADIOSONDE TEMPERATURE AND RELATIVE HUMIDITY DATA

by

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ABSTRACT

Computer processing of rawinsonde data is necessary at missile ranges to satisfy range user requirements for various atmospheric parameters. Computer methods exist for processing military radiosondes; however, these methods are not applicable to reducing temperature and humidity data from the U. S. Weather Bureau sondes of the Environmental Science Services Administration.

This report presents equations for the derivation of temperature and relative humidity from the incoming signal of the U. S. Weather Bureau radiosonde with the fast-response humidity element.

CONTENTS

Section I. INTRODUCTION

The problem of computer processing radiosonde data has been investigated. Computer methods exist for processing data from military sondes; however, these methods are not applicable to reducing data from the Environmental Science Services Administration sondes (U. S. Weather Bureau (USWB)).

In the event these sondes are used in place of military sondes at missile ranges, it is necessary that "manual evaluators" be eliminated and that incoming radiosonde signals be processed by computer methods.

U. S. Weather Bureau personnel and also the manufacturer of the USWB sondes were contacted before starting this investigation. It was learned from the developer of the evaluator that no equations were used and that the humidity evaluator was derived from averages of test data. Several investigators have attempted unsuccessfully to derive single curve methods for computer processing the USWB sonde data. In this study, however, a split of the data from the humidity evaluator into two parts and application of a multiple regression technique resulted in reasonable equations. This was the most favorable of several approaches investigated and requires only two equations for the reduction of relative humidity. Thus, the problems of single curve fitting are circumvented.

The purpose of this report is to present the equations for derivation of temperature and humidity data from the recorder division values of the USWB radiosondes with the carbon humidity element.

Section II. DERIVATION OF TEMPERATURE DATA

To derive temperature from the incoming radiosonde signal, compute the resistance pertaining to a given recorder division or ordinate using:

$$\ell g_{10}\left(48000 + R_T\right) = 6.952316 - 0.9966256\ \ell g_{10}\ (2D) \qquad (1)$$

where R_T = resistance in ohms

D = ordinate.

Compute temperature in °K pertaining to resistance R_T using

$$\frac{1}{T} = 0.00330033 + 0.00107701\ \ell g_{10}\left(M\frac{R_T}{14000}\right)$$

$$+ 0.0000589986\left[\ell g_{10}\left(M\frac{R_T}{14000}\right)\right]^2 \qquad (2)$$

where T = temperature in °K

M = baseline check constant.

1. Derivation of Baseline Constant M

The baseline constant can be obtained from the two general expressions, Equations (1) and (2), and the baseline values of recorder division, D_B, and baseline temperature, T_B (°K), as follows.

Converting Equations (1) and (2) respectively to base e, we obtain

$$\ell n\left(48000 + R_T\right) = 16.0082991 - 0.9966256\ \ell n\ (2D) \qquad (3)$$

$$\frac{1}{T} = 0.00330033 + 0.00046774\ \ell n\left(M\frac{R_T}{14000}\right)$$

$$+ 0.0000111278\left[\ell n\left(M\frac{R_T}{14000}\right)\right]^2. \qquad (4)$$

By substituting D_B into Equation (3) and solving for baseline resistance in ohms, R_{T_B} is obtained as

$$R_{T_B} = \left[e^{16.0082991 - 0.9966256 \, \ln\left(2D_B\right)} \right] - 48000 \ . \qquad (5)$$

Let $\ln\left(M \frac{R_{T_B}}{14000}\right)$ be denoted as X and Equation (4) as a quadratic equation in X, and then

$$X = \frac{-b + \sqrt{b^2 - 4ac}}{2a}$$

where $b = 0.00247991$
$a = 0.0000589986$
$c = 5.3018981 \left[0.00330033 - \frac{1}{T} \right].$

The positive root is taken because the negative root gives an impossible value for T in Equation (4), and also the numerical value of X is always greater than zero.

The baseline constant is thus obtained from the expression:

$$M = \frac{14000}{R_{T_B}} \, e^{X} \ . \qquad (6)$$

The numerical value of M is now substituted in Equation (4) and held constant for the particular radiosonde flight.

2. Field Procedure for Solving Temperature

a. Baseline Constant

From the baseline data, the recorder division D_B, and the associated baseline temperature T_B, calculate the baseline constant, M.

$$M = \frac{14000}{R_{T_B}} \exp \frac{\left[-b + \sqrt{b^2 - 4ac}\right]}{2a}$$

where $b = 0.00247991$

$a = 0.0000589986$

$c = 5.3018981 \left[0.00330033 - \frac{i}{T_B} \right]$

$$R_{T_B} = \exp \left[16.0082991 - 0.9966256 \, \ell n \, (2 D_B) \right] -48000 \, .$$

b. Radiosonde Flight Temperature

Using numerical value of M and the recorder division values, D, from the radiosonde flight, compute the resistance R_T by

$$R_T = \exp \left[16.0082991 - 0.9966256 \, \ell n \, (2D) \right] -48000$$

and substitute in the expression

$$\frac{1}{T} = 0.00330033 + 0.00046774 \, \ell n \left(M \frac{R_T}{14000} \right) + 0.0000111278 \left[\ell n \left(M \frac{R_T}{14000} \right) \right]^2$$

and then solve for T (°K).

Section III. DERIVATION OF RELATIVE HUMIDITY

The computation of relative humidity from the recorder division values is more complex than the derivation of temperature data. Relative humidity is a function of baseline lock-in, temperature, and ordinate.

The following expressions have been derived on a 7094 computer by multiple linear regression. These expressions are based on the entire range of data and temperatures.

For ordinate $D \leqq 60$

$$\begin{aligned} RH = {} & 8.4079\times10^{-2}\ B - 9.2007\times10^{-2}\ D + 1.2687\times10^{-1}\ T \\ & + 1.3426\times10^{-4}\ B\,D - 7.4676\times10^{-10}\ D^4 + 3.7020\times10^{-10}\ T\,D^3 \\ & - 2.5669\times10^{-15}\ P^{?} + 4.7002\times10^{-15}\ D^6 + 4.6706\times10^{1}\ . \end{aligned} \tag{7}$$

For ordinate $D > 60$

$$\begin{aligned} RH = {} & 1.0489\times10^{-1}\ B + 2.0422\times10^{-6}\ D^3 - 1.4068\times10^{-4}\ B^2 \\ & + 5.0362\times10^{-4}\ B\,D + 2.8783\times10^{-4}\ B\,T - 1.2081\times10^{-3}\ D^2 \\ & + 2.9082\times10^{-9}\ T\,B^3 - 4.2336\times10^{-9}\ T\,D^5 + 9.3054\times10^{-15}\ B^3\,D^3 \\ & - 1.8825\times10^{-14}\ D^6 + 4.2082\times10^{1}\ . \end{aligned} \tag{8}$$

Correction: $28 > RH \geqq 16$ subtract 2 from RH

where $B = 10B' - 500$
$D = 10D' - 500$
B' = ordinate read at 50-percent relative humidity after baseline lock-in
D' = recorder division value from radiosonde
T = temperature from radiosonde, °C .

The standard error of relative humidity from Equation (7) is 1.0 percent; from Equation (8) the standard error is 1.6 percent. The standard error is much smaller when the correction is applied as indicated to Equation (8).

Section IV. CONCLUSIONS

Equations have been presented for derivation of temperature and relative humidity data from the incoming signal of the USWB radiosonde. These equations, when used with the standard equations for computing various thermodynamic and wind data, enable computer processing of the USWB sondes in a manner similar to those used for reduction of the military sondes.

A more simplified method of deriving relative humidity, however, is being investigated. The method is based on least squares fit of the data and is applicable to the entire range of data if proper baseline constant is utilized. The goal is to derive humidity within one percent of the humidity evaluator values. Three equations are therefore required because of the nonlinearity of the humidity evaluator. Two equations have been developed which fit the data within one percent for recorder division values greater than 25. One equation covers the ordinate range 25 to 75 and the other equation covers for ordinate values greater than 75. A third equation is required for ordinates less than 25. Investigations will continue to develop an equation within one percent for these ordinate values.

These equations will be completed and included in the technical report for deriving temperature and humidity data.